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HEATING APPLIANCE CONTROL SYSTEM

Background of the Invention

Field of the Invention

The present invention generally relates to control of heating appliance features, and more specifically relates to controlling a heating appliance flame and coordinating changes in the flame with sound and scent production in the heating appliance.

Related Art

Generally, heat generation in a heating appliance is altered by controlling the source of energy being used to generate heat. Most known heating appliances include some type of heat control system that facilitates on/off control, the level of heat output, and possibly thermostatic control that involves monitoring room temperature and turns the heating appliance on or off in order to maintain a certain temperature within the room. In the case of a gas powered heating appliance such as a gas fireplace or stove, heat generation is controlled by altering the flow of gas to a burner via a gas valve.

Decorative heating appliances such as fireplaces and stoves typically include a combustion chamber of some type wherein heat is generated or simulated in the form of a flame, and the flame is viewable for aesthetic purposes. Many fireplaces and stoves that burn a gaseous substance rather than a solid fuel like wood or other fibrous material attempt to produce a flame or flame effect that simulates burning of a solid fuel. Burning of a solid fuel not only produces flame modulations but also produces a variety of burning sounds such as crackling and snapping sounds, and different burning scents that are not commonly associated with burning a gaseous fuel. A heating device that provides improved heating control and simulation of a solid fuel flame is desirable.

Summary of the Invention

The present invention generally relates to a heating appliance that is configured to provide flame and heat control based on a flame signal indicative of a selected flame characteristic. The flame characteristic may correspond to the frequency and amplitude of the flame, or may relate to a mean flame temperature over time, flame color, size, movement patter, or other physical or aesthetic characteristic of the flame. The heating appliance may also include a scent delivery system and a sound system that function independently or in synchronization with the flame characteristics.

One aspect of the invention relates to a gas fireplace that includes a combustion chamber enclosure defining a combustion chamber, a burner positioned to generate a flame within the combustion chamber enclosure, a variable valve coupled to the burner, a module coupled to the variable valve, and an input device. The module is configured to generate a control signal for use by the variable valve to adjust a flow of combustible fuel delivered to the burner to generate at least one flame characteristic. The input device may be used for selecting one of the flame characteristics.

Another aspect of the invention relates to a gas fireplace that includes a combustion chamber enclosure defining a combustion chamber, a burner positioned to generate a flame within the combustion chamber enclosure, a variable valve configured to provide a combustible fuel to the burner, and an input device configured for selection of at least one flame effect. The fireplace also includes a module coupled to the variable valve that is configured to control the variable valve according to one of a plurality selected flame effects thereby controlling fuel flow to the burner.

A further aspect of the invention relates to a flame control system that includes an input device configured to provide selection of at least one flame effect, a module configured produce a control signal corresponding to the at least one flame effect, and a flame modulator configured to modulate a flame in response to the control signal.

A yet further aspect of the invention relates to a heating appliance that includes a combustion chamber enclosure defining a combustion chamber for the combustion of fuel, a burner configured to produce combust the fuel to produce a flame,

valve configured to control fuel flow to the burner, and a controller configured to generate a flame control signal that is delivered to the valve, the valve controlling fuel flow in response to the flame control signal to alter an amplitude and frequency of the flame.

Another aspect of the invention relates to a flame and sound system configured for use with a heating appliance. The system includes an input device configured for selection of at least one user preference, a control module configured to generate a flame control signal and a sound control signal in response to the selected user preference, a flame modulator configured to modulate a flame in response to the flame control signal, and a sound generating device configured to produce sound in response to the sound control signal.

A further aspect of the invention relates to a method of controlling a flame that includes selecting at least one flame indicator using a input device, generating a flame control signal with a control module, the flame control signal corresponding to the at least one selected flame indicator, and controlling a flame characteristic in accordance with the flame control signal.

A yet further aspect of the invention relates to a method of controlling a gas fireplace assembly that includes a burner, a valve, a sound system, a scent delivery system, and a control module. The method includes generating a control signal with control module and communicating the control signal to the valve, the sound system, and the scent delivery system, controlling a fuel flow from the gas valve to the burner in response to the control signal, controlling production of sound by the system in response to the control signal, and controlling production of scent by the scent delivery system in response to the control signal.

Another aspect of the invention relates to a method of thermostatically controlling a flame. The method includes providing a first room temperature measurement, setting a target room temperature, generating a flame having a first flame amplitude configured to provide heat sufficient to attain the target room temperature, providing a second room temperature measurement, determining a difference between the target room temperature and the second room temperature measurement, and

altering the first flame amplitude to a second flame amplitude when the determined difference is within a predetermined temperature range of the target room temperature.

The above summary of the present invention is not intended to describe each disclosed embodiment or every implementation of the present invention. Figures in the detailed description that follow more particularly exemplify embodiments of the invention. While certain embodiments will be illustrated and describing embodiments of the invention, the invention is not limited to use in such embodiments.

Brief Description of the Drawings

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

Figure 1 is a front perspective view of an example fireplace assembly incorporating features and systems of the invention;

Figure 2 is an exploded perspective view of the fireplace assembly shown in Figure 1;

Figure 3 is a perspective view of an example valve assembly according to principles of the invention;

Figure 4 is a cross-sectional view of the valve assembly shown in Figure 3 taken along cross-sectional indicators 4-4;

Figure 5 is a front view of an example control panel according to principles of the invention;

Figure 6 is a schematic representation of an example control system according to the invention;

Figure 7 is a schematic representation of example features of the invention;

Figure 8 is a schematic representation of further example features of the invention;

Figure 9 is a schematic representation of an example control system according to principles of the invention;

Figure 10 is an example grid showing combinations of flame mode and style options;

Figure 11 is a graph showing results of a first style in burn down mode;

Figure 12 is a graph showing results of a second style in burn down mode;

Figure 13 is a graph showing results of a third in style burn down mode;

Figure 14 is a graph showing results of a fourth style in constant mode;

Figure 15 is a graph showing results of a fifth style in burn up mode;

Figure 16 is a graph showing results of a sixth style in thermostatic control mode;

Figure 17 is a flow diagram showing example user selection options at a control panel;

Figure 18 is a flow diagram showing an example method of flame, sound and scent in a heating appliance;

Figure 19 is a flow diagram showing an example method of thermostatically controlling a flame;

Figure 20 is a flow diagram showing an example method of controlling features of a heating appliance based on the time and calendar inputs;

Figure 21 is a schematic diagram showing communication between a heating appliance control system and database; and

Figure 22 is a schematic front perspective view of an example scent cartridge and scent heating element according to principles of the invention.

While the invention is amenable to various modifications and alternate forms, specifics thereof have been shown by way of example and the drawings, and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

Detailed Description of the Preferred Embodiment

The present invention generally relates to control of heating appliance features and more specifically relates to controlling a heating appliance flame and coordinating changes in flame characteristics with sound and scent production in the heating appliance.

One heating appliance for which the present invention may be particularly useful is a fireplace that includes a combustion chamber enclosure defining a combustion chamber and a front surface through which the combustion chamber is viewable. A flame provided in the combustion chamber produces heat and a decorative flame effect. Energy in the form of, for example, a combustible fuel, may be delivered to the combustion chamber in a controlled manner to control both the heat generated by the flame and the appearance of the flame.

One example flame control system includes a variable valve that controls modulation of a flame burning in the combustion chamber by controlling the flow of fuel through the valve. An opening in the valve can be controlled according to a specific style of flame modulation related to the flame frequency and absolute temperature, or may be controlled according to a certain mode of flame burn over time which is related to a mean temperature of the flame over time. The opening and closing of the valve to produce the style and mode of the flame may be controlled in a response to a control signal generated by a controller. The controller may also synchronize or otherwise control generation of sound and scent production in the heating appliance that corresponds to the flame style and mode. Auxiliary features of the heating appliance may also be controlled by the controller independently or in synchronization with changes in the flame characteristics, the sound, and the scent being generated. Example heating appliance auxiliary features include an ember bed, lights, and blowers that may be activated by the controller.

As used herein, the term "combustion chamber enclosure" can be any structure that at least partially surrounds that portion of the fireplace or heating appliance in which combustion or heat generation or simulation of heat generation occurs. A combustion chamber enclosure typically includes a plurality of panels that

define a combustion chamber for the combustion of fuel or generation of heat using other means. The term "living space" will be understood to mean the interior or inner portion of a dwelling structure, such as a house or office building. The term "heating appliance" is defined as any appliance or apparatus configured to provide a source of heat and preferably an aesthetic function, and may include such appliances as gas fireplaces, electric fireplaces, heaters, furnaces, and stoves. Some example fireplaces that may be used in conjunction with the control system of the present invention include a direct vent, a universal vent, a B-vent, a horizontal/vertical-vent, a dual direct vent, and a multi-sided unit having three or more glass panels as combustion chamber side panels. While the present invention is not so limited, an appreciation of various aspects of the invention will be gained through a discussion of the examples provided below. The term "flame characteristic" and "flame effect" may be defined as including the frequency and amplitude, and may relate to a mean flame temperature over time, flame color, size, movement patter, or other physical or aesthetic characteristic or effect of the flame.

Referring now to Figs. 1 and 2, an example heating appliance assembly 10 in the form of a fireplace is shown and described. Assembly 10 includes an outer enclosure 12, a combustion chamber assembly 14, a control assembly 16, a valve assembly 18, a burner assembly 20, a viewing panel 22, a control panel 24, a lighting assembly 26 and a blower 28. The outer enclosure 12 includes an inner cavity 30 and an opening 32 formed in a front surface thereof to provide visual access into a combustion chamber 36 defined by a combustion chamber enclosure 34 of the combustion chamber assembly 14. The control assembly 16 includes a controller 50 and a power module 52. The controller 50 may include memory that is either stored with the controller or stored at a remote location. The valve assembly 18 includes a valve 38 and inlet and outlet fuel lines 40, 42. The burner assembly 20 includes a burner plate 46 and a grate 48. The lighting assembly 26 includes a light bulb 54 and a light housing 56. The blower 28 is positioned within the outer enclosure 12 and may be used to move heated air within the outer enclosure 12.

Referring now to Fig. 3, the valve 38 includes a base 60, a primary fuel valve assembly 62 that includes first and second end plates 64, 66, a hollow tubing member 68 having a threaded end 70, first and second magnets 72, 74 positioned within the tubing member 68, a wire coil 76 positioned between the first and second end plates 64, 66, and an adjustment member 78. The adjustment member 78 alters a position of the first magnet 72 relative to the second magnet 74 within the hollow tubing member 68.

The valve 38 can be made continuously adjustable by applying a variable pressure to a pressure setting portion of the valve that controls the flow of a gaseous fluid through the valve. This variable pressure is produced by utilizing the force produced by a magnet acting in a magnetic field generated by the wire coil 76. In one example, the coil 76 is made by winding an AWG (American Wire Gauge) magnet wire about 2300 turns in a coil configuration, the first and second end plates 64, 66 may be separate brass disks spaced apart about 0.9 inches along the tubing member 68, and the tubing member 68 may be a 0.25 inch brass tubing that is about 1.5 inches long.

The first and second magnets 72, 74 may be, for example, Neodymium, Alnico, Samarium-Cobalt, or any other suitable magnets that provide the required reaction to forces produced by the energized coil 76. The second magnet 74 is moved in the tube 68 relative to the base 60 by the mutual repulsion of the first magnet 72 and by the magnetic field generated in the axial direction when a current is applied to the coil 76, thereby creating a gas pressure change in the base 60. The second magnet 74 may also be held in place by means of a spring (not shown), although the spring should have little to no friction against the inner sides of the tubing member 68 so as to minimize hysteresis and to be non-magnetic. A magnetic spring may be attracted to the magnet and produce discrete steps thereby eliminating the continuously variable properties of the valve assembly.

In use, the adjustment member 78 is adjusted to produce the maximum desired flow with no power applied to the wire coil 76. To vary the gas pressure within base 60, a positive current applied to the coil 76 moves the first and second magnets 72, 74 in a first axial direction relative to the base 60, and a negative current applied to the

coil 76 moves the first and second magnets 72, 74 in a second axial direction relative to the base 60 in a direction opposite of the first axial direction. Moving the second magnet 74 either increases or decreasing the gas pressure in the base 60 depending on the direction of motion relative to the valve 68. In one embodiment, the operating pressure of the valve 38 is about 1.7 to about 3.5 inches of water, and preferably about 2.2 to about 3.5 inches of water. These pressure ranges may be well suited for generating heat output in the heating appliance of about 27,000 to about 35,000 BTUs.

If the current applied to the coil 76 is modulated between positive and negative values, the pressure in valve 68 will inversely follow the modulation of the current applied to the coil 76. If the polarity of both of the magnets is reversed, the pressure in base 60 will directly follow the modulation in the current applied to the coil 76. Other embodiments may include only a single magnet positioned in the coil, which configuration provides the same or similar effects as described above for valve assembly 62 while providing a reduced axial force when a current in applied to the coil 76 as compared to a double magnet configuration.

The amount of current applied to coil 76 relates directly to the distance the magnets 72, 74 travel relative to base 60, thereby providing a direct correlation with the gas pressure changes in the base 60. As a result, increasing current to the coil results in an increase (or decrease depending on the magnet polarity) in the gas pressure in the base 60 which will then increase (or decrease) the amount of gas flowing through valve 38 to, for example, a gas burner that produces a flame. Likewise, decreasing current to the coil results in a decrease (or increase) in the gas pressure in the base 60 which will then decrease (or increase) the amount of gas flowing through valve 38. Controlling the current flow can thus be used to control the flow of combustible gas to a burner with relative precision.

The friction of the first and second magnets 72, 74 in the tube member 68 is preferably kept as low as possible to provide consistent performance and minimum hysteresis. The magnets 72, 74 may be coated with a low friction material such as Teflon, and an inner surface of the tubing member 68 may also be coated with a similar low friction material. The hysteresis of the valve assembly may be shown on a

plot (not shown) using an XY recorder with current one axis and gas pressure on the other axis. As the current is increased to the wire coil 76, one line will be drawn on the graph and as the current is decreased another line will be drawn on the graph. The distance between the two lines is the hysteresis.

A minimum pressure can be set in the valve 38 by mechanically adjusting the adjustment member 78 so that the primary valve assembly 62 is set at a minimum pressure desired. The maximum pressure may be limited for safety reasons using a configuration in which, for example, the first magnet 72 is stopped by the head structure provided at an end of the adjustment member 78. By reversing either or both of the first and second magnets 72, 78 or the polarity of the wire coil 76, the gas pressure can be increased with increasing current applied to the coil 76 rather than decreasing with increased coil current. In this way, the pressure in the valve can be made to both increase and decrease by driving the wire coil 76 with a bipolar current. An example bipolar current can be provided by varying a DC current or using a pulse with a modulated current.

Other devices that may be used in place of the fuel valve assembly 62 of valve 38 include, for example, linear actuators, stepper motors, or a heat sensitive material in a bi-metallic switch that deforms under varying heat conditions. An example heat sensitive material that may be used is NiTi, sometimes known as Nitinol, which is known to deform when heated, for example, by running a current through the material.

The control panel 24 may be used as a user interface with the control assembly 16. Communication between the control panel 24 and the control assembly 16 can be facilitated using any system or technology capable of transmitting control signals such as, for example, a drawn wire, radio frequency (RF), infrared (IR), cellular, satellite, ultrasound or optics. The control panel 24 may include some basic computer related components such as a microprocessor, memory, digital to analog (D/A) and analog to digital (A/D) converters and various input and output devices. In other embodiments, the control panel 24 may be a simple input device and all processing associated with the inputs is handled by the control assembly 16.

The example control panel 24 shown in Fig. 5 includes a base 80, a display screen 82, and a keypad 84. The display screen 82 provides indicators associated with the changes entered into the system via the keypad 84. In other embodiments, the keypad 84 may be integrated into the display screen when the display screen includes touch screen capabilities, wherein discrete areas of the display screen are active and are capable of receiving inputs via a touch input by a user.

The keypad 84 includes a plurality of keys or actuators for controlling certain features of the heating appliance assembly 10. For example, the keypad 84 may include a fan actuator 86, a cold climate actuator 88, a flame mode actuator 92, a flame style actuator 94, an auxiliary flame actuator 96, up and down actuators 98, 100, and a sound control actuator 102. The display screen provides visual indicators of the system settings controlled through the keypad 84. For example, display screen 82 may include an on/off indicator 104, a timer indicator 106, a room temperature indicator 108, a target room temperature indicator 110, a fan level indicator 112, a lighting indicator 114, a flame style indicator 116, an auxiliary flame indicator 118, a battery life indicator 120, a cold climate indicator 122, and a sound system indicator 124.

The fan actuator 86 may be used to control certain speeds of the blower 28 to circulate air heated between the outer enclosure 12 and the combustion chamber assembly 14 and exhaust that heated air back into the living space or to a remote area. An example blower and associated venting system is shown and described in U.S. Patent Application No. 10/769,557, filed on January 30, 2004 and entitled EXHAUST SYSTEM FOR OPEN FRONT FIREPLACE, which application is incorporated herein by reference in its entirety.

The cold climate actuator 88 may be used to maintain a minimum source of heat generation in the combustion chamber by, for example, burning a pilot light or maintaining a relatively small flame at the burner plate 46 at substantially all times or according to a thermostatic control. Such a generation of heat may be useful for eliminating a cold air draft entering the combustion chamber in reverse flow through the heating appliance exhaust vent or for maintaining a minimum temperature in the living space. The light actuator 90 may be used to activate an ember bed (not shown)

associated with the burner assembly 20, or to activate the lighting assembly 26 or other lighting features (not shown) associated with the heating appliance assembly 10.

Although an ember bed is not shown, an example electric ember device for use in a fireplace is shown and described in U.S. Published Patent Application No. 2002/0166554A1, filed on May 9, 2001 and entitled ELECTRIC EMBER BED, which patent application is incorporated herein by reference in its entirety. An example backlighting system for use with a fireplace is shown and described in U.S. Patent application No. 10/719,037, filed on November 19, 2003 and entitled BACKLIGHTING SYSTEM FOR A FIREPLACE, which patent application is also incorporated herein by reference in its entirety. An ember bed and a lighting system may be controlled through the controller 50. For example, the controller 50 may be used to generate ember bed control signals and lighting control signals that are sent to the ember bed and light producing fixture to facilitate modulation or other alterations of the ember look or lighting. Control of the ember bed and lighting may be independent of the flame, sound and scent characteristics, or may be control in synchronization with the flame, sound and scent characteristics.

The flame mode actuator 92 may be used to select between one or more flame modes associated with a mean flame temperature over time. Some example flame modes that may be selected via the flame mode actuator 92 are described in further detail below and may include, for example, a burn down mode, a constant flame mode, a burn up mode, or a thermostatically controlled mode. The control panel 24 does not include an indicator related to the flame mode selection, although such an indicator may be added to display screen 82 in other embodiments.

The flame style actuator 94 is used to select between one or more flame styles associated with such flame characteristics as, for example, a flame frequency and a flame absolute temperature. Flame modulation frequency and absolute amplitude may correspond to random or pseudo-random inputs that are used by the control assembly 16 to generate a flame control signal that controls fuel flow through the valve assembly 18 to the burner 46. Flame characteristics such as modulation frequency and absolute amplitude may be independently selectable and controllable or may be interdependent

with each other. In one embodiment, a single algorithm is used for a selected flame style and separate timing crystals (or other random or pseudo-random numeric generation device) are used to generate numeric inputs related to the flame frequency and absolute amplitude, respectively. In another embodiment separate algorithms are used to generate the flame frequency and absolute temperature using a single timing crystal. Timing crystals may include a predetermined range of values that are established by the crystal structure and set using a clock signal. The timing crystal provides "pseudo-random" numeric values in that the values are randomly chosen from within the established range.

Various flame styles will be described in further detail below and may include any suitable combination of different flame frequencies and absolute amplitudes that can be individually selectable and/or provided automatically with, for example, a flame mode selection, a cold climate selection, or an auxiliary flame actuator selection. Some control panel and control assembly embodiments may be pre-programmed with or include pre-selectable activators and buttons for certain combinations of available flame characteristics, style, modes, and other options for the heating appliance assembly. Auxiliary flame actuator 96 may be used to select other flame characteristics or to actuate secondary flames, simulated flames, or other flame-related features associated with heating appliance assembly 10.

The up and down actuators 98, 100 may be used to raise or lower a value associated with, for example, the timer, target room temperature, fans speeds, flame styles, or volume of a sound system.

The sound control actuator 102 may be used to select between a variety of different sound tracks either directly or indirectly, choose between different sound volumes, and provide an on/off switch for a predetermined sound that is associated with, for example, certain flame modes or flame styles. Additional sound related features of heating appliance assembly 10 are described in further detail below.

Referring now to Fig. 6, an example control assembly 16 may include a multiplier 120, a CPU 122, memory 124, communication connections 126, removable storage 128, non-removable storage 130, output devices 132, input devices 134, a D/A

converter 136, an A/D converter 138 and a power supply 52. These features of control assembly 16 are common to many known computing devices. Other embodiments of controller system 16 may include more or fewer components as needed for a given application. The CPU (central processing unit) 122 may be any suitable processor typically capable of being programmed, receiving input signals, and generating output signals based on programmed code, algorithms, commands, etc., or may generally be defined as a controller capable of receiving inputs and producing outputs.

The memory may be volatile (such as RAM), non-volatile (such as ROM, flash memory, etc.) or some combination of the two. The removable and non-removable storage 128, 130 may include, but not be limited to, a magnetic disk drive, an optical disk drive, or a hard disk drive. Other storage media may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules, or other data. The memory 124, removable storage 128 and non-removable storage 130 are all examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disk (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the controller 50.

The communications connection 126 facilitates communication between controller 50 and other devices. Communications connection 126 is an example of communication media. Communication media typically includes computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wire connection, and wireless media such as

acoustic, RF, IR and other wireless media. The term "computer readable media" as used herein includes both storage media and communication media.

The input devices 114 may include, for example, one or more of the following: a keyboard, mouse, pin, voice input device, touch input device, etc., such as the control panel 24. Output devices 116 include, for example, a display, speakers, printer, burner, lights, scent generating devices, etc., which devices can be positioned together with other output devices or at a location remote to the control assembly 16. All these devices are well known in the art and need not be discussed at further length. Although the control assembly 16 is shown as being mounted within the outer enclosure 12 of the heating appliance assembly 10, other embodiments may include a controller that is positioned at a remote location or may include controller components that are positioned at a remote location and accessible through some type of communication network or connection. For example, program modules used by the CPU may be located in both local and remote computer storage media including memory storage devices. In one such example (as shown in Fig. 21), the heating appliance controller system 220 may communicate through a communications network 222 with a remote database. Such a communications network 222 may include the Internet, satellite, cellular, or other wireless communications systems to connect the controller system 220 with additional information such as program modules, algorithms, digital sound tracks, or other information necessary for controlling certain features of the heating appliance assembly 10.

The multiplier 120 may be used to generate inputs for use by the program modules and algorithms used by CPU 122. In other embodiments, output generated from the program modules and/or algorithms executed by CPU 122 may be passed through the multiplier 120 before further processing and delivery to other features of the heating appliance assembly 10. A divider or other linear or non-linear value altering device may be used in place of multiplier 120 to produce the desired result. In one example, a single algorithm and single timing crystal may be used for three different styles that are available for selection by a user, and different control signals related to each of the three styles is determined by the multiplied or divided

value applied to the output from the algorithm by the multiplier/divider. In either configuration, selection of the multiplier/divider and program modules/algorithms themselves or inputs to those devices may be dependent on the inputs selected by a user at the control panel 24. The random nature of the signal generation using random or pseudo-random inputs results in a lower probability of repeating a sequence of control signals, which reduced repeatability may be advantageous for improving the look and feel of a flame and related flame effects.

Referring now to Fig. 7, one aspect of the invention relates to an example system having an input device 140, a control assembly 142, and a heating appliance 144 having a flame modulator 146. Input from the input device 144 provided to the control assembly 142 is used to control a flame via the flame modulator 146. The input device 140 may be any suitable system or device, such as, for example, control panel 24, remote control device, or buttons and controls directly mounted to the control assembly 142 that provide input signals to the control assembly 142. The control assembly 142 may include one or more components such as a CPU, memory, storage devices, input and output devices, digital to analog and analog to digital converters and communications systems that together receive inputs or that is preprogrammed with certain information for program modules that are executable to provide a flame control signal to the flame modulator 146. The flame modulator 146 may be a valve, valve component, burner, or other device that controls flame generation by, for example, controlling fuel flow or other conditions that affect a flame characteristic. The flame modulator 146 may be positioned within or in close proximity to a heating appliance 144 to modulate or in some way control a flame or a simulated flame in response to flame signals provided by the control assembly 142.

Although many of the examples described herein refer to generation and control of an actual flame and characteristics of the flame, similar principles may apply to generation and control of a simulated flame. For example, control signals generated by the control assembly 142 may be used to control a flame modulator that includes, for example, blowers, rotary devices, lighting, image generation devices, and other devices or structures that may be used to simulate a flame.

Referring now to Fig. 8, another aspect of the invention relates to an example system that includes input from a control assembly 150 and a flame modulator 152. In this embodiment, the input 150 may be an electronic signal, data stream, or other formatted information capable of altering functions of a flame modulator. The flame modulator may be any suitable device configured for controlling an actual flame or simulated flame using, for example, a mechanism that controls the flow of fuel or power or information that corresponds to changes in the flame or simulated flame.

Referring now to Fig. 9, an example control system 160 including features and functionality in accordance with certain aspects of the invention is shown and described. Control system 160 includes a control assembly 162, a control panel 164, a flame control system 166, a sound control system 168, a scent control system 170, and an auxiliary control system 172. The features of panel 164 and systems 166, 168, 170 are not limited by those features shown and described with reference to the system 160.

The control assembly 162 may include a processor such as a CPU and may also include memory and other features necessary to communication with the panel 164 and systems 166, 168, 170, 172. An example controller for use in the control assembly 162 may be the control assembly 16 described above.

The control panel 164 includes a display 180, an input device 182, and memory 184, and may include further features and functionality as described above with reference to control panel 24 described above and shown in Fig. 5.

The flame control system 166 may include a high/low solenoid control 190, a high/low solenoid 192, an H-bridge 194, a variable gas valve solenoid 196, and on/off control 198. One example flame control system 166 may include the fuel valve assembly 62 described above with reference to valve 38 and shown in Figs. 3 and 4. Other flame control systems may include alternative gas valve components used to control gaseous fuel flow through a valve. In other example flame control systems, such as a system that utilizes a simulated flame, the flame control system may be limited to the flow of voltage, current, or other power source that has a corresponding effect upon the appearance of a simulated flame.

The sound control system 168 may include a CPLD (complex programmable logic device) 200, flash memory 202, a D/A converter 204, and an audio out device 206. The sound control system 168 may include a number of sound tracks in either a digital or analog format that can be selected in response to signals from the control assembly 162 to produce sound signals at the audio out device 206. In one example embodiment, the sound control system 168 includes multiple sound tracks each having a pre-determined track length and sound sequence. In such a system, signals from the control assembly 162 provide activation of one or more of the sound tracks to provide different sound production from the control system 160.

One example sound control system 168 that includes a minimum memory storage requirement includes eight different sound tracks that each provide a different sound and have a duration of about two to four seconds. Sound signals from the control assembly 162 correspond to different flame styles and modes as described above and different sound tracks or accumulated use of multiple sound tracks may correspond to different flame scenarios. For example, a high frequency, high absolute amplitude flame may correspond with a sound signal from the control assembly 162 that accesses all eight sound tracks, whereas a very low frequency, low absolute amplitude flame would correspond to a sound signal from control assembly 162 that accesses only one or two of the sound tracks. In another example, the various sound tracks may be selected randomly or selection of the tracks may be chosen based on a pattern of interchanging or repeating tracks over time. Such a pattern may correspond to a particular flame characteristic related to a selected flame style and mode.

In other embodiments, each of the eight sound tracks may include different sounds with the same or different volume, or the same sounds with different volumes. In another example control system that may require extensive amounts of memory space/usage is a system that has two or more different sound tracks having lengthy durations (e.g., 20 seconds to about 2 minutes) that are selectable for a particular style and/or mode of the flame. For example, a given flame style and mode selection via the control panel 164 may correspond to a sound signal from control assembly 162 that accesses a single track that plays repeatedly rather than playing

multiple tracks concurrently or in series with each other. In another embodiment, a volume produced from each track may increase or decrease depending on the size of a generated flame.

In still further embodiments, the sound control system 168 may include sounds that do not correspond to the flame or simulated flame provided by the flame control system 166. For example, the sound control system 168 may include sound tracks corresponding to certain seasons of the year (e.g., Spring or Fall), weather conditions (e.g., wind, rain, thunder), music preferences of a user (e.g., Rock, Jazz, Classical), or the time of day (e.g., morning or night) in which the control system is being used. Such non-flame related sound tracks may be pre-selected individually by a user via the control panel 164, or may be selected automatically in response to preprogrammed program modules or algorithms/inputs provided to the control assembly 162. The sound control system 168 may be connected to an remote music source through, for example, a wireless LAN or cable connection.

An alternative sound related system that may be useful in some embodiments of the invention includes a sound monitoring or collecting device such as a microphone that collects sounds, provides inputs to the control system based on the collected sound, and the control system adjusts flame characteristics, sound and scent outputs, and other system outputs based on the sound related inputs. In one example configuration, a microphone is used to collect sounds from a room in which the heating appliance resides, and the flame frequency and fire related sound output is increased or decreased depending on the amount of "noise" in the room. In one scenario when a user is reading a book in a quiet room, the fire frequency and absolute temperature may be reduced and the fire related sounds generated by the sound system may also be reduced to a low volume. In a second scenario when the same room is full of people in load conversation, the flame frequency and absolute temperature and fire related sounds may be increased automatically in response to the level of "noise" collected by the microphone. The collect "noise" may be the intensity or volume of sound measured, for example, in decibels, or it may be a measurement of different sound tones, frequencies, etc. generated in a room.

The scent control system 170 may include a signal adapter 210, a heating element 212, and a scent cartridge 214 that can be inserted into a slot 213 formed in the heating element 212, as shown in Figure 22. Scents generated by scent control system 170 are typically intended to replicate volatile organic compounds (VOCs) that are emitted when burning wood and other fibrous materials. The scent cartridge 214 typically includes materials that emit actual or replicated VOCs when heated, and are typically designed to resist combustion when heated to temperatures common present within the heating appliance (e.g., temperature within a combustion chamber of a fireplace). In one embodiment, the scent control system 170 may be configured to receive a scent signal from the control assembly 162, adapt that scent signal to a signal format that controls the heating element 212 that is in contact with the scent cartridge 214 thereby producing a scent. Many known scent cartridges produce a scent in response to heat. For example, a piece of wood such as cedar can be placed adjacent to and heated by a primary source of heat in a heating appliance.

Heating scent cartridge 214 may be accomplished using the separate heating element 212 such that the scent cartridge can be heated somewhat independently of the primary source of heat in the heating appliance. In this configuration, the heating element 212 is the main source of heat for heating the scent cartridge to produce scent. Other embodiments may use a combination of heat sources to heat the scent cartridge. For example, the scent control system may be positioned adjacent to or in close proximity to the primary source of heat in the heating appliance (e.g., a burner within a combustion chamber enclosure of a fireplace) such that scent production directly correlates with a mean temperature of the flame and/or heat source provided in the heating appliance. An example combined heating source for a scent system includes an artificial log wherein the heating element is embedded in the log and is also contacted by a flame in the combustion chamber.

Many scent control systems have a delayed scent generating effect in that the scent cartridge must be heated to a certain temperature prior to producing a given amount of scent. To compensate for this delay, the scent control system 170 may be a "smart" system that predicts future flame conditions based on trends in the flame

characteristics (e.g., flame temperature and flame size) and controls the heating element 212 to either increase or decrease heat supplied to the scent cartridge 214 in advance of the existence of the predicted flame characteristic so that the proper scent intensity is provided concurrently with production of the actual flame characteristic.

The scent control system 170 may be used in correlation with a blower or fan (e.g., blower 28 shown in Figure 2) that distributes the scent generated by the scent cartridge. The blower speed may be controlled, for example, using control system 162, to increase or decrease scent distribution to correspond with certain flame characteristics such as the absolute or mean temperature of the flame. For example, the blower speed may be increased along with increased heating by heating element 212 such that the overall scent production better correlates with an increase in mean flame temperature.

The auxiliary system 172 may include a lighting system such as an electric ember bed or backlighting system, a fan/blower or other air moving device, or other feature of a heating appliance that may be controlled in response to signals provided by control assembly 162.

The control assembly 162 may be configured to send signals to each of the systems 166, 168, 170, 172 that are coordinated and provide some element of synchronous performance or activation of each of the systems. For example, a flame signal provided from the control assembly 162 to the flame control system 166 may relate to an increased mean temperature of a flame produced in response to a certain open position of a gas valve, while the control assembly 162 may provide at the same time a scent signal to the scent control system 170 that corresponds to an increase in scent production, and also send a sound signal to the sound control system 162 that correlates to a higher volume or more active sound representative of a higher temperature flame. Such a use of control system 162 is representative by the process flow diagram shown in Fig. 18. Thus, the functions of systems 166, 168, 170, 172 can also act or be set independently from one another, or can be synchronized in any desired combination.

Fig. 18 illustrates the steps of a user selecting flame characteristics at a control panel such as a flame style and mode, a signal being sent from the control panel to the control board, the control board accessing information from memory, and the control board calculating control signals based on an algorithm or program module. The control signals include a sound control signal sent to the sound system, a flame control signal sent to a valve, and a scent control system for the delivery system. In response to the sound control signal, the sound system accesses stored sound information and produces a specific sound. In response to the flame control signal, the flame control system modulates a flame or simulated flame. In response to the scent control signal, the scent delivery system varies scent generation in the heating appliance.

With reference to Fig. 10, a flame or simulated flame production in the heating appliance may be controlled according to different modes and styles. The optional combination of various modes and styles provide the plurality of options available to a user (for example, available choices for a user via a control panel). Each style and mode may be selected and used individually and independently, or may be used in combination with other styles and modes. Some example flame modes include a burn down mode, a constant flame mode, a burn up mode, or a thermostatically control mode. A burn down mode is representative of a solid fuel burning fire that uses a discreet amount of solid fuel, which is commonly known to build to a peak flame size and/or temperature, and then reduced to a low temperature, low flame size fire over a set time period. A constant flame mode relates to a fire that has a set flame absolute amplitude and a flame frequency that is constant or varies in a repeatable way, and preferably has a constant mean flame amplitude over time. A burn up mode is representative of a solid fuel fire in which the fire begins with a very small flame amplitude and mean temperature and builds slowly over time to a peak flame absolute and mean temperature and frequency. In the burn up mode, the flame characteristics such as flame frequency and absolute temperature may continue to vary over time after reaching the peak mean temperature. A thermostatically controlled mode relates to a flame that is limited to a certain room temperature (thermostat reading), and controls the

mean temperature of the flame over time so as to maintain the predetermined room temperature without turning the flame on and off as is common in most thermostatically controlled heating appliances.

Some example flame styles include a "wild" fire in which the flame has a high frequency and high flame absolute amplitude, a "laid back" style in which the flame frequency is relatively low and the flame absolute amplitude is relatively small, and a "romantic" style in which the flame frequency is typically between the wild and laid back frequencies and the flame absolute amplitude is set at any suitable value. Fig. 11 is a graphical representation of the electronic signals (voltage or current) sent from a controller to a variable gas valve for the production of a wild style flame in a burn down mode. The peak-to-peak value of each cycle represents an absolute value of the flame temperature, the frequency of the signal is measured between each cycle, and the mean value of the signal over time represents the mean temperature of the flame. Figs. 12 and 13 represent respective laid back and romantic flame styles in a burn down mode. It can be seen from Figs. 12 and 13 that the frequency is much lower than the wild style and that the absolute temperature of the flame corresponding to the signal is substantially equivalent to that of the wild fire, although the absolute amplitude may be different in other embodiments. The "burn down" mode is represented by the mean value of the signal, which increases slightly initially in time and then slowly decreases to a minimum value at the end of the time period.

Fig. 14 illustrates a constant flame mode in which the voltage signal to the variable valve is set to a mean flame temperature. Although Fig. 14 illustrates the flame having a high frequency modulation, some embodiments may include a flame with little to no modulation (i.e., frequency equal to zero) so that the flame is merely on at a constant valve opening condition.

Fig. 15 illustrates a burn up mode in which the mean flame temperature increases over time and the flame absolute temperature also increases over time to a peak value. In some embodiments, multiple modes may be combined over a fixed time period. For example, the user may be able to program the controller to produce a constant flame for a first hour and then a burn down mode for the subsequent hour. The

controller may also be controlled based on a timer in which the controller actuates the flame control system at a predetermined time of day to produce a certain flame mode and style for a certain time period.

Referring now to Fig. 16, a thermostatically controlled mode is shown with reference to a temperature versus time scale. As the mean flame temperature approaches the target temperature, the flame control signal is modified to produce a mean flame temperature that moves toward and away from the target temperature typically in a sinusoidal modulation as shown in Fig. 16.

Fig. 19 provides a flow diagram of an example method of using the thermostatically controlled mode. The user initially chooses a target temperature (T_T), a flame mode (thermostatic mode) and possibly a flame style (e.g., wild, laid back, romantic that relate to a flame frequency and absolute temperature). A room temperature reading is taken, which, for example, can be measured at the input device 24 as shown in Figs. 1 and 2 and provided with the other user selections to the controller. The controller then uses the inputted information to produce a flame signal that corresponds to a mean flame temperature projected to reach the targeted temperature T_T. At certain intervals of time (t_2, t_3) the room temperature readings (T_2, T_3), are provided to the controller and the controller determines a difference between the target temperature and the temperature in each of the pre-selected time periods to generate a flame factor (ΔT) and then recalculates and sends a new flame signal to the variable valve based on a projected room temperature that will result from the flame signal. This process is repeated over time as the mean temperature of the flame changes and the room temperature changes so as to maintain a room temperature at or below the targeted room temperature. This process may be modified in different ways to provide a constant room temperature or a range of room temperatures without the need to ever turn the flame off. In some embodiments, the system may shut off the flame if the room temperature reaches a certain level above the target temperature (e.g., 5 or more degrees above the target temperature), which may be necessary if, for example, a certain style of flame is selected or if the flame is burning for an extended period of time in a substantially sealed room.

The above described thermostatically controlled mode may be used to adjust a room temperature from 70°F (temperature = T_1 at time = t_1) to a target temperature of 80°F (T_T at time = t_i). This 10 degree temperature change defines a flame factor range of 1 to 10. If a second temperature reading (T_2 = 76°F) is taken at t_2, and the new flame factor is 4 ($\Delta T = T_2 - T_T$). The control system may use the flame factor of 4 as an indicator that the target temperature of 80°F will be approaching within a relatively short time period given the selected flame characteristics (e.g., flame frequency and absolute temperature). As a result of this evaluation, the control system may reduce the flame absolute temperature slightly while maintaining the flame frequency, or implement some other change in the flame characteristics that would reduce the mean temperature output of the flame. A third temperature reading (T_3 = 79°F) may be taken at t_3, and the new flame factor is 1 ($\Delta T = T_3 - T_T$). With a flame factor of only 1, the control system may need to more significantly modify some flame characteristic in order to avoid overshooting the target temperature. A fourth temperature reading (T_4 = 78°F) may be taken at t_4, and the new flame factor is 2 ($\Delta T = T_4 - T_T$). With a flame factor of 2 after having more modified certain flame characteristics at t_3, the control system may now look forward and predict that the room temperature will continue to decrease at the current setting and will then modify the flame characteristics to increase the heat output of the flame. This cycle of monitoring the room temperature, determining a flame factor, and adjust the flame characteristics may be repeated continuously or may be used in combination with other flame modes to provide the desired room temperature and flame characteristics.

Referring now to Fig. 20, as noted above, the controller may be provided with a clock and calendar and programmed with certain program modules or algorithms that are activating in response to certain user selections of flame style and mode. The controller may provide a flame style and mode and sound selection based on either or both of the user selections and/or the time of day or day of the year. For example, certain configurations may provide for background sounds of birds chirping if the flame is activated in the early morning hours on a spring day in the month of March, or the

sound of crickets, nightfall or other nighttime sounds may be activated when the flame is produced in the nighttime hours during a summer month of July.

Generation of a flame, sound, scent or other signal from the controller of the control system may be generated in at least one of the two following ways. In one configuration, a single signal generating algorithm is used or a separate algorithm for each of the flame, sound, scent and other outputs, and numerical values unique to each flame style, mode or combination thereof is provided to the algorithm for processing by a multiplier. A separate multiplier may be used for each flame style and mode or combination of styles and modes, for example, a separate multiplier for each of the combinations shown in the grid of Fig. 10. In another configuration, a separate algorithm may be used for each chosen flame style and mode and a multiplier may or may not be used to further process the outputs from the algorithm before they are sent to the respective flame, sound, scent, and auxiliary systems. In still further embodiments, the numeric inputs and multiplier values may be stored in a table or array of values that is stored in memory and accessed by the control system as necessary.

The present invention should not be considered limited to the particular examples or materials described above, but rather should be understood to cover all aspect of the invention as fairly set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art to which the present invention is directed upon review of the instant specification.